Thermal Hazard Analysis for TSE Processes

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Background

- Thermal decompositions experienced during propellant simulant processing with the 40-mm and the 37-mm TSEs
- No conclusive findings as to the root cause of the decomposition event
- Phase 1 effort:
  - Investigated various insults that may occur in TSE processing
  - Ranked and selected critical insults
  - Selected thermal hazards around the screw tip boundary area

Objective

- To develop a method to characterize the thermal hazards of energetic materials throughout TSE process scale up and determine safe processing windows for TSE processes
- The methods should be cost effective and available in a short period of time

Approach

- Characterize material hazards
  - Predict the self accelerating decomposition temperature (SADT) and time-to-maximum rate
  - Validate results with small-scale test
- TSE process development
  - TSE process simulation software for process design
  - Obtain general process responses
- Predict material responses of TSE processes
  - Develop a model to predict material temperature
  - Estimate the highest material temperature within a specific boundary area
  - Validate predictions with experimental process run

TSE Characterization Method

Process
Design/Simulation

"WinTXS"

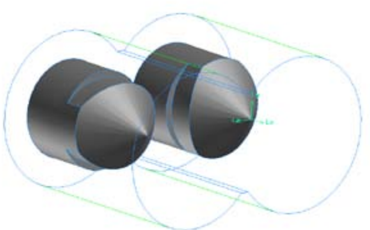
Material Response Model
Across TSE Geometry
Boundary Area

"In-House Model Using
Fluent"

Thermal Hazard
Characterization

"In-House Capability"
and/or AKTS Models

Define Safe TSE
Operational Window



Thermal Hazard Characterization

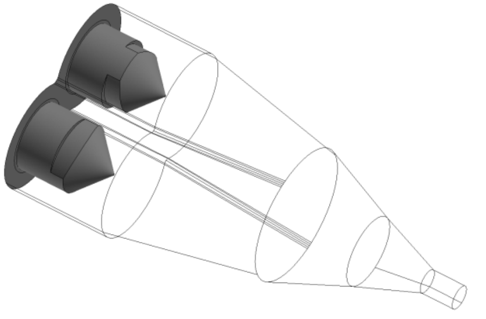
- Characterize the decomposition kinetics with DSC tests
  - ASTM Standards (internal resources)
  - AKTS Thermokinetics Software (contracted resources)
- Predict SADT and time-to-maximum rate
  - Frank-Kamenetskii (internal resources)
  - AKTS Thermal Safety (contracted resources)
  - Use simple geometries such as slabs and cylinders to represent the internal material volume of 20, 37, 40 and 88mm TSE

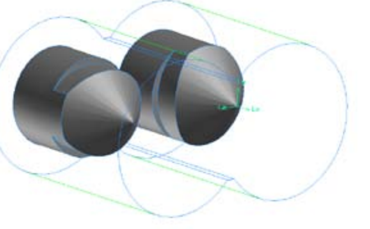
Process Design/Simulation

- WinTXS will be used as follows:
  - Design screw and barrel configurations
  - Simulate average process responses at various conditions
  - Optimize screw and barrel design
  - Simulate the boundary conditions required for the material response model
  - Process scale up design

Material Response Model

- Predict the temperature of the volume of material around the screw tips and toward the die entrance
- CFD Simulation w/ Fluent Software
  - Use of Herschel-Bulkley viscosity function
  - Include the rotation of the screw-tips
  - Need to evaluate Fluent capabilities





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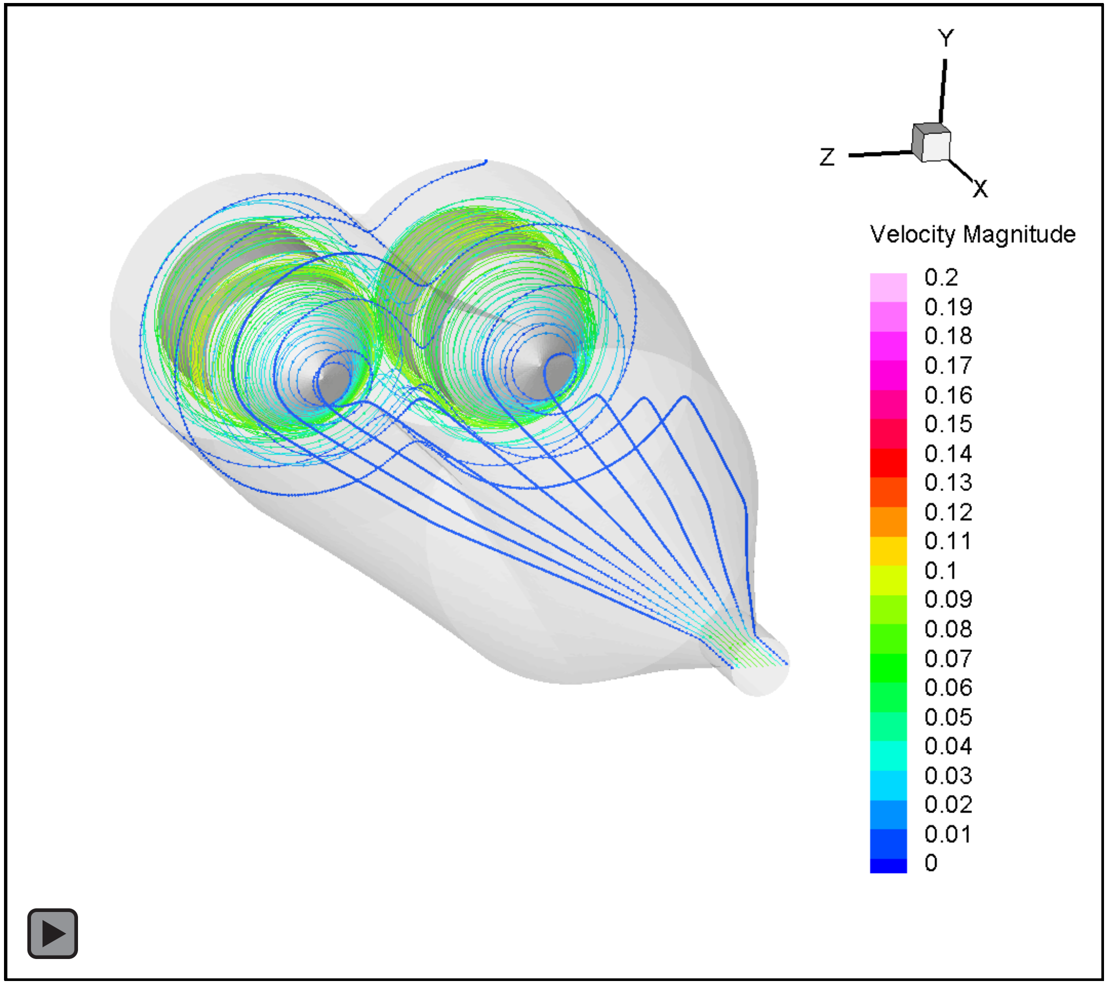
Material Response Model (Cont.)



Accomplishments

- Critical insult mechanism selected
- Received modeling recommendations for
  - TSE material response model using Fluent software
  - Thermal Hazards predictions using ASTM standards and AKTS Thermal Safety Software
- Selected WinTXS TSE Simulation Software by PolyTech for process design and modeling
- Chilworth Technology teamed with AKTS-Switzerland will perform high pressure DSC tests and thermal hazard evaluation of a new propellant formulation with AKTS Thermal Hazard Software
- Material response modeling started
  - Geometry Completed
  - Material properties defined
  - Moving model development ongoing

Future Work

- Thermal hazard model validation
  - Predict the time-to-maximum rate of a propellant pellet sample at various temperatures
  - Predict the SADT of the pellet sample
  - Perform small scale test to validate model predictions
- Learn WinTXS and simulate a TSE process
- Experimental TSE process run to validate the process and material response model